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# **A Pressure Microphone with Spherical Acoustic Surface**

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In studio practice, there are practically only two forms of the modern single-diaphragm pressure microphone:

- the cylindrical (rod-type) and
- the flat (boundary layer or pressure-zone type)

Generally speaking, studio microphones are faced with two diametrically opposed requirements:

On the one hand, the diaphragm surface should be as small as possible for the best transmission characteristics over the entire audible range, independently of frequency and direction. On the other hand, the diaphragm has to deliver an adequate output level for a high s/n ratio, which for its part stipulates a certain minimum diaphragm area. Rod microphones generally compromise with a diameter of about 20 mm.

Since a microphone is used in free space in the studio and is required to pick up sound from all directions, it is not only the diaphragm diameter which has to be taken into consideration, but also the dimensions of the microphone body as a whole, which by its very presence, has an influence on the sound field. With a microphone diameter of 20 mm for instance, the result, in the upper frequency range, is both a pressure build-

up characteristic for frontal sound impingement and the occurrence of direction-dependent shadowing and diffraction effects. The microphone therefore does not reproduce just the original sound field, but the original plus alterations superimposed on it by the fact of its own presence.

As for the pressure build-up caused by the movement of air particles in front of the almost sound-reflecting diaphragm, it is endeavoured to shift this into the region of the highest possible frequencies by making the end face of the cylindrical microphone very small or, by dint of incorporating the diaphragm in a large surface, to shift the pressure build-up into such a low frequency region that the microphone is subjected to it over its entire range of response. It is then acting as a boundary-layer microphone and is thus again able to function independently of frequency. At the same time, a microphone of this type, by incorporation in a limiting surface which is present in any case, is withdrawn out of the sound field, and is no longer able to cause any interference [1].

## **The Capsule Body**

Now it is certain that the dream of both microphone manufacturers and users will continue to be pursued of producing an (almost) non-present and a noise- and distortion-free transducer. Alternatively, one can regard a microphone body as a necessary evil and consider whether other practical designs might be evolved which would not interfere with the sound field as much as a cylinder.

Fig. 1 shows the development of the sound pressure at the marked locations on the surfaces of various bodies in free sound field. Here the overall dimensions of the bodies are coordinate-wise equal, thus permitting a qualitative comparison of the frequency responses. It is intended to demonstrate that at the end face of a cylinder, for instance, fundamentally other pressure build-up conditions are manifested than on bodies with other shapes. In addition, it is apparent that the sound pressure level in front of a rod-type microphone rises by up to 10 dB, and it is not only a doubling of the pressure which occurs.

The most even development is achieved on a spherical surface. It is also interesting to note how the sound pressure changes on the “front side” of the sphere when there is no “rear side”. The same applies for bodies of other shapes. Thus, it is not the same thing whether a microphone diaphragm forms the end face of a long cylinder or constitutes a disc in free sound field (example: dual-diaphragm capsule).

Fig. 2 depicts various sound impingement angles for two of the bodies illustrated in the foregoing: cylinder and sphere. It was apparent in Fig. 1 that the pressure build-up in front of a sphere is very even and extends only as far as a doubling (6 dB rise), but it is seen in Fig. 2 that this “smooth” development also applies to other sound impingement angles. <sup>\*)</sup>

Furthermore it is obvious that level variations among various impingement angles are greater with a cylindrical design than with a spherical body.

## The Archtype

At the beginning of the Fifties, a microphone was produced by NEUMANN in which a 12 mm diameter condenser capsule was located in a spherical body 40 mm in diameter. This configuration, somewhat removed from the tube amplifier, was free-mounted behind a wire gauze grille, the diaphragm being parallel to the microphone housing (Fig. 3) [2].

What we have here then is a combination of the bodies discussed in the foregoing “cylinder end face” (= microphone capsule) and “spherical body”, the characteristics of which - corresponding to the ratio of wavelength to body dimensions transposed - are rediscovered, for example, in the 0° frequency response of this microphone, Fig. 4:

- the flat rise from 1 kHz upwards with a maximum lift of 6 dB (sphere characteristics)
- the fall-off above 10 kHz (cylinder surface and capsule characteristic)
- and a dip around 4 kHz caused by diffraction and reflection at the amplifier housing.

After 20 years of manufacture, this microphone was - and still is - extremely popular, partly because of some of the characteristic properties described above. For this reason we have decided to take up this concept once again.

Another special feature of this microphone not previously mentioned is the capsule: By the use of an 8 μm thin metallic diaphragm and a diaphragm spacing of only 10 μm (with condenser pressure microphones, this is twice as much as a rule), a high sensitivity and low equivalent noise level have been attained.

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<sup>\*)</sup> In the case of the sphere, “zero degrees” is defined in practice only by the circumstance that a microphone diaphragm can regrettably not be constructed as a “breathing sphere”. but is a flat surface section of the sphere with a surface normal.

## Selection of Diaphragm Material

Unfortunately there are no metal foils on the world's markets which meet our requirements regarding thickness constancy, freedom from porosity and surface quality. For this reason we decided to make the diaphragms for this pressure transducer by our own electroplating methods. This afforded us the freedom to determine the thickness of the diaphragm ourselves, i.e. to examine, with the aid of acoustic measurements and listening tests, whether there were still any audible differences below 10  $\mu\text{m}$  diaphragm thickness.

Metrologically the tests were carried out with the aid of the transient response of the various capsules. Parameters were the thickness of the diaphragm, its mechanical tension and the diaphragm material.

Fig. 5 shows the transient response diagrams of two "extremes", as far as the diaphragm thickness is concerned: 2.25  $\mu\text{m}$  (top) and 10  $\mu\text{m}$  (centre). At the bottom, for purposes of comparison and as a supplementary criterion, is the oscillogram of a breaking glass with a maximum frequency of 20 kHz.

As might be expected, the transient response reflects directly the diaphragm mass. The thinner or the lowest in mass the diaphragm, the shorter the attack time, i.e. the width of the first impulse. It should be borne in mind here though, that the diaphragm cannot act on its own - both the cushion of air in front of the diaphragm and the enclosed volume behind it make a considerable contribution to the mass, amounting in fact to some 30% to 75%, depending on the capsule design. However, since the volume behind the diaphragm, like the diaphragm spacing of this particular capsule, is very small, the average width of the reproduced impulse is extremely short - no more than some 8.5  $\mu\text{s}$ .

Following these objective measurable values, which do not by themselves provide any evidence of quality, we proceeded to the much more complicated question of subjective assessment. Since hearing and the interpretation of things heard is not an absolute process, as everyone knows, we decided to make use of a comparison capsule. For this purpose, it seemed only logical to use an "original" capsule from past production. We therefore had five microphones of identical construction, the capsules of which were covered with five different diaphragms, compared by sound engineers. Diaphragms of aluminium, nickel and titanium were used with thicknesses between

2.25  $\mu\text{m}$  and 10  $\mu\text{m}$ . Differences in output level were smaller than 0.5 dB below 5 kHz and somewhat larger above 5 kHz, depending on the diaphragm used, but in no case greater than 1 dB. The measured impulse widths had values between 7.9  $\mu\text{s}$  and 11.6  $\mu\text{s}$ , whereby an impulse width of 10  $\mu\text{s}$  corresponds to a limit frequency of 50 kHz.

No doubt it would be possible to deliver a lecture just on the differences in sound produced by these five microphones, but on the other hand the lecturer would have to define what an audible difference actually is. As the above-mentioned measured results indicate, the audible differences were naturally very small, and therefore the selection of the reference capsule was almost a matter of personal preference. For each one of the five microphones we received descriptions of the sound which had reference to distinctive characteristics in various frequency ranges. Naturally such statements did not result in any clear order of merit, but nevertheless pointed the way to a decision in favour of the 2.25  $\mu\text{m}$  diaphragm, which delivered the shortest measured impulse width.

## **The Housing**

Already prior to these detailed listening tests for the selection of the diaphragm material, it had been established in several series of measurements and again in subjective tests that it is not necessary to mount the capsule arrangement in such a sizeable housing as was axiomatic in the age of the vacuum tube. Accordingly, the smaller and handier housing and grill form shown in Fig. 6 was evolved.

## **The Circuitry**

The microphone capsule and the first amplifier stage are built into the plexiglass sphere. Therefore the signal path in the grill down to the other circuitry is low-impedance. This means that the wire gauze grill could be made particularly open in the acoustical sense without any danger of hum or RF interference.

In the lower part of the microphone is a switchable high-pass filter stage and the dc converter, which generates the voltage necessary for the amplifier and capsule from the 48 V phantom powering circuit.

The output level of the microphone can be reduced by 10 dB by means of a second switch.

## Summary

A condenser pressure microphone has been developed which, by the nature of its capsule design, has a particularly short transient response and exploits the acoustical pressure build-up and diffraction properties of a spherical surface (Fig. 7):

- the smooth rise in the pressure build-up range for frequencies above 1000 Hz,
- a maximum pressure rise of 6 dB in the 8 kHz region,
- the early and even increase in the directivity index with rising frequency, whereby - likewise due to the spherical surface - the frequency responses for side and rear sound incidence are almost identical.

In the middle and upper frequency range, the microphone exhibits directional properties which are almost comparable with those of a pressure-gradient microphone, while at the same time featuring as a pressure transducer a sensitivity which is linear all the way down to the lowest frequencies.

The amplifier circuitry is transformerless and corresponds to that of our "fet 100" series.

The microphone is the TLM 50.

## Literature:

- [1] B. Müller: "A new Type of Boundary-Layer Microphone"  
Paper read at the 88th AES Convention, Montreux 1990
- [2] H. Grosskopf: "Neue Kondensatormikrophone für Rundfunk-Studios"  
FTZ 1951, No. 9

Fig. 1 and 2 are from the book "Acoustical Engineering", Chapter I, by Harry F. Olson, D. van Nostrand Comp., INC. Princeton, New Jersey.

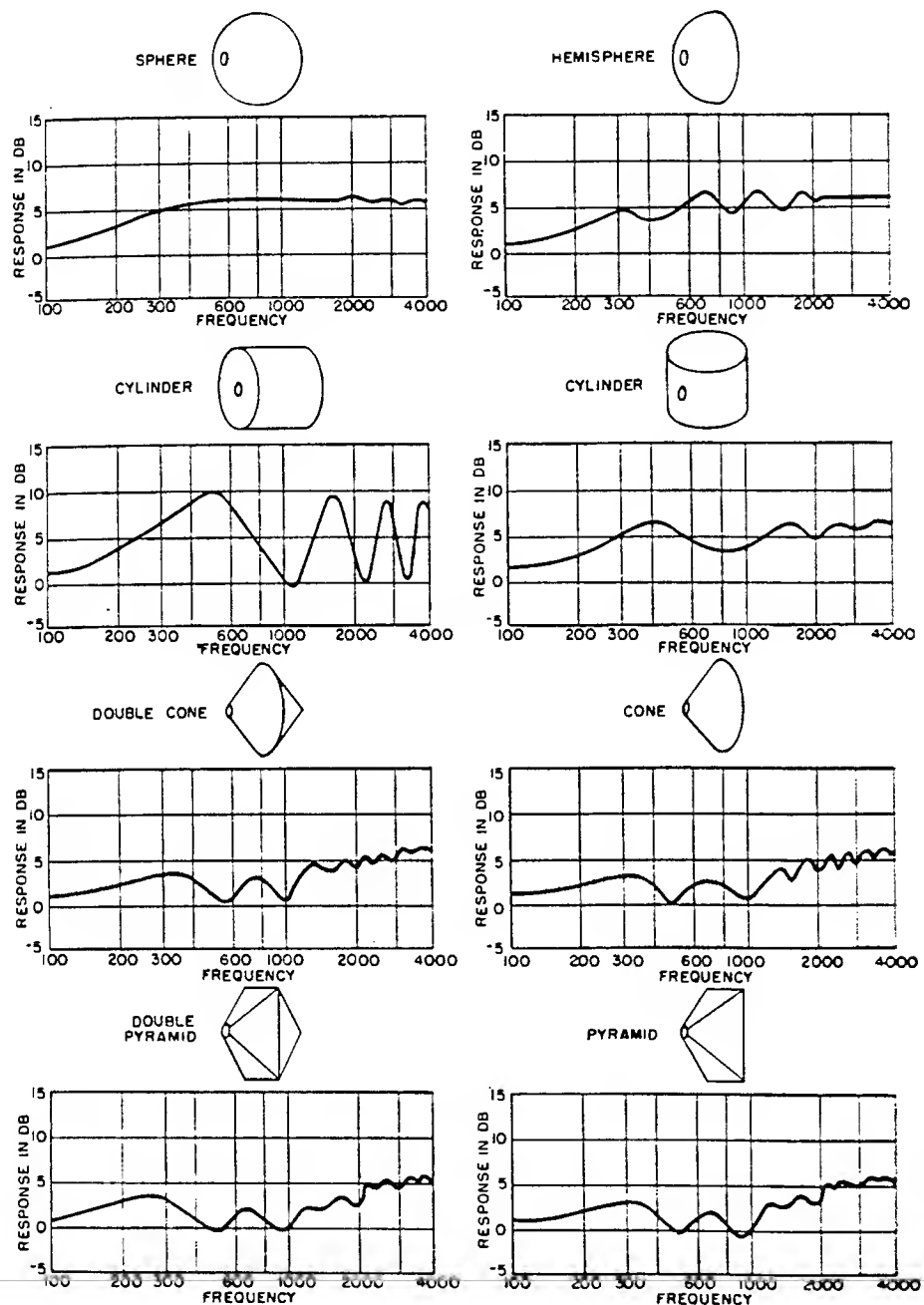


Abb. 1  
Fig. 1

Schalldruckpegelverläufe an unterschiedlich geformten Körpern  
Response frequency characteristics at objects of different shapes

GEORG NEUMANN GMBH

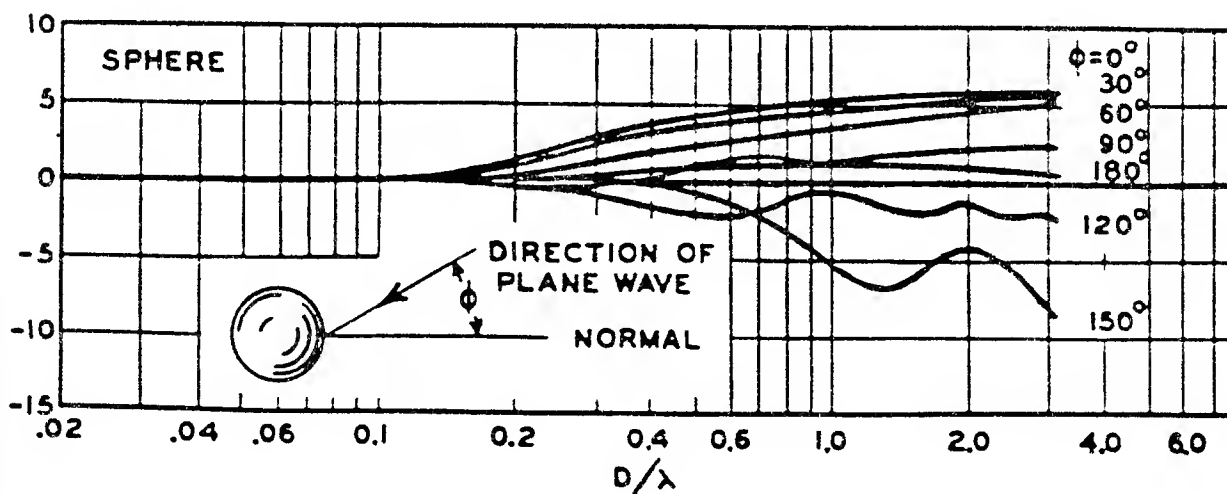
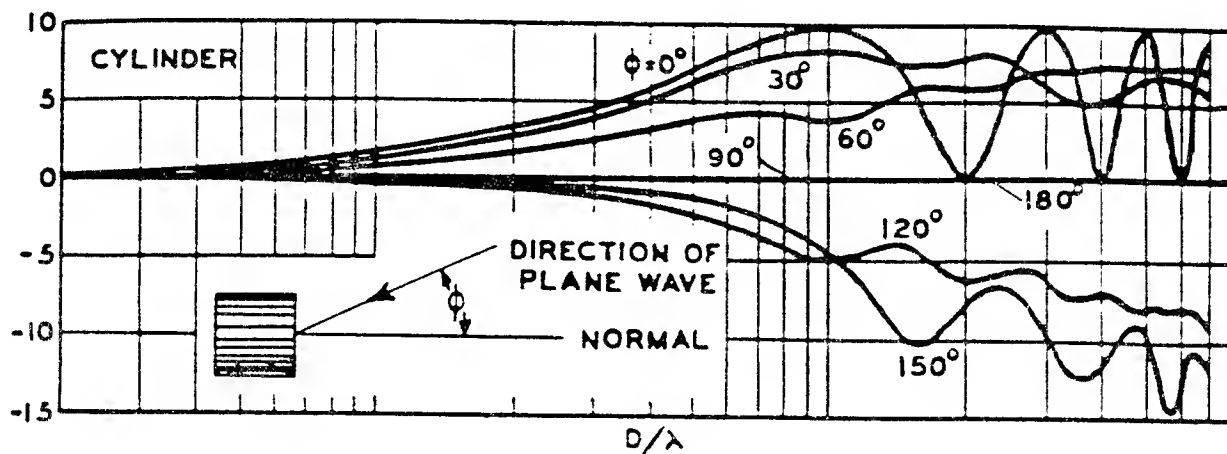


Abb. 2  
Fig. 2

Winkelabhängigkeit des Schalldruckpegelverlaufs an Zylinderstirnfläche und Kugel  
The diffraction of a sound wave by a cylinder and sphere

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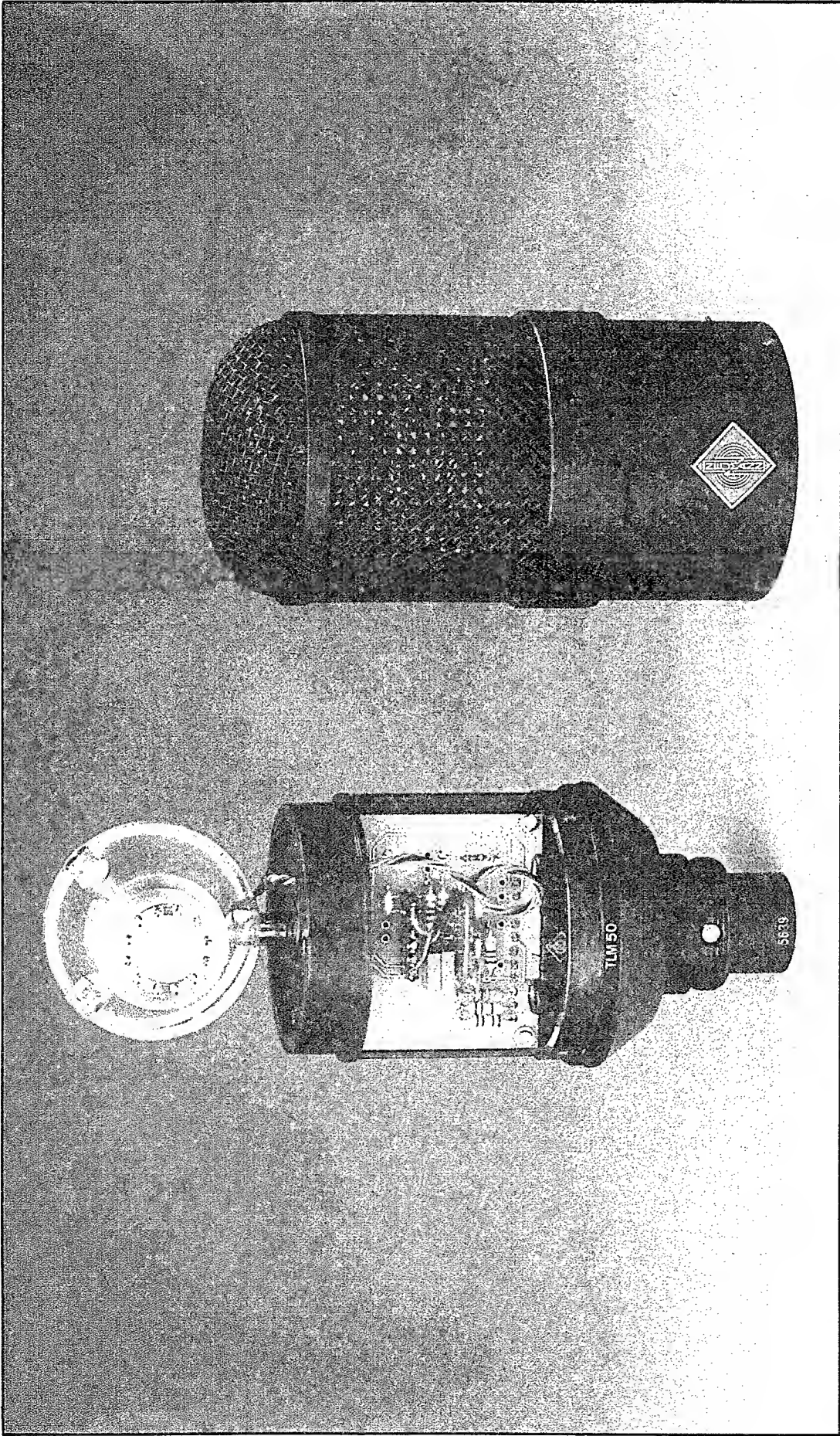


Abb. 3

Fig. 3

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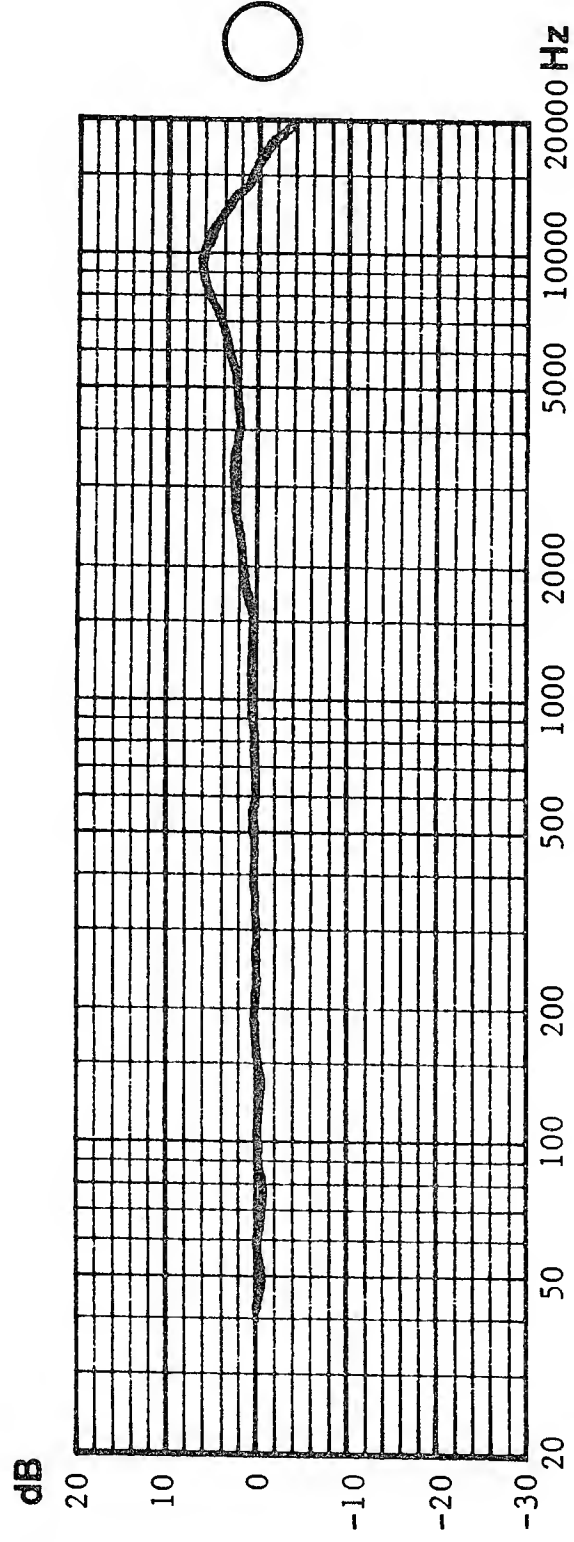


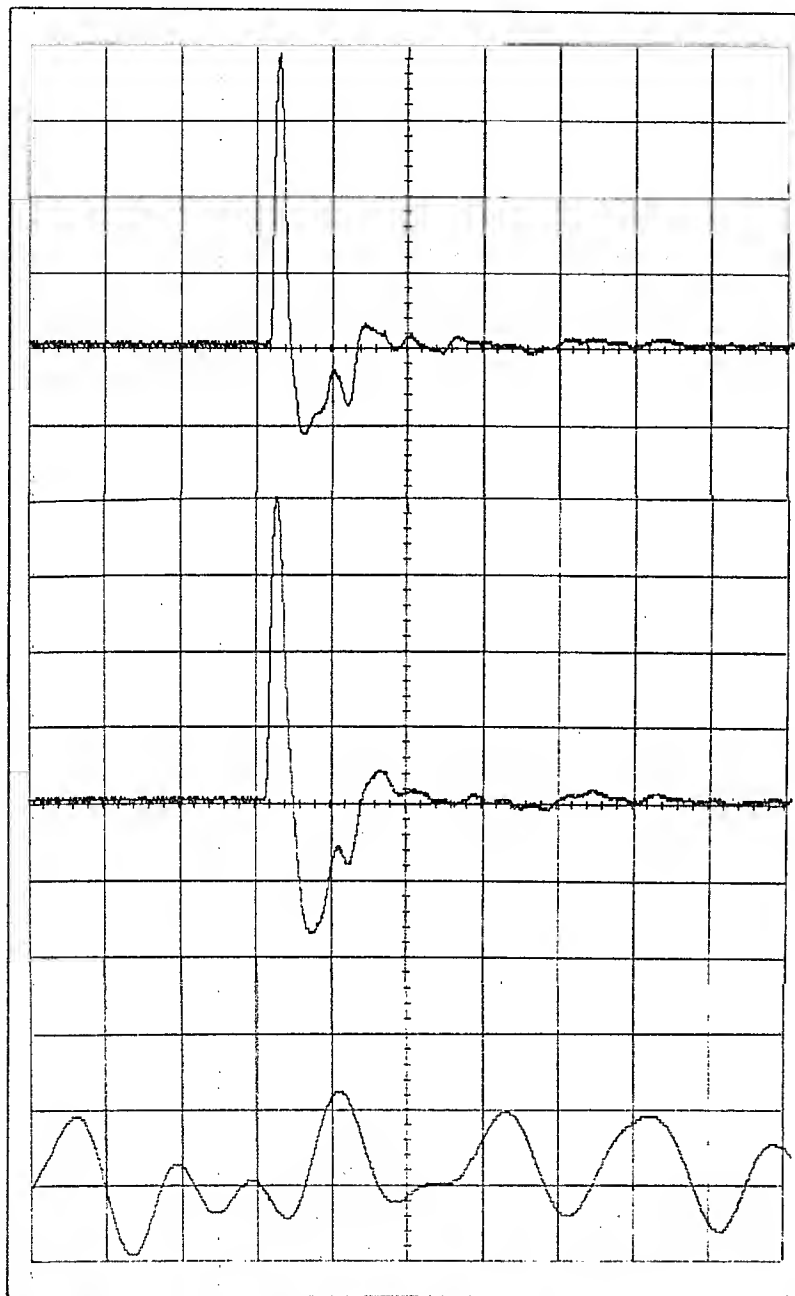
Abb. 4

Fig. 4

0°-Frequenzgang des Röhrenmikrophons M 50

0°-Frequency response of the M 50 tube microphone

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DATE: Aug 23/89

TIME: 14:10:23

CH1: 0.20V : 50µs

2.25 µm Nickelmembrane

10 µm Nickelmembrane

Gläserklirren  
Clinking of glasses

50 µs/Div  $\hat{=}$  20 kHz

Abb. 5

Fig. 5

Impulsantworten des TLM 50 mit zwei verschiedenen Membranen

Transient response of the TLM 50 with two different membranes

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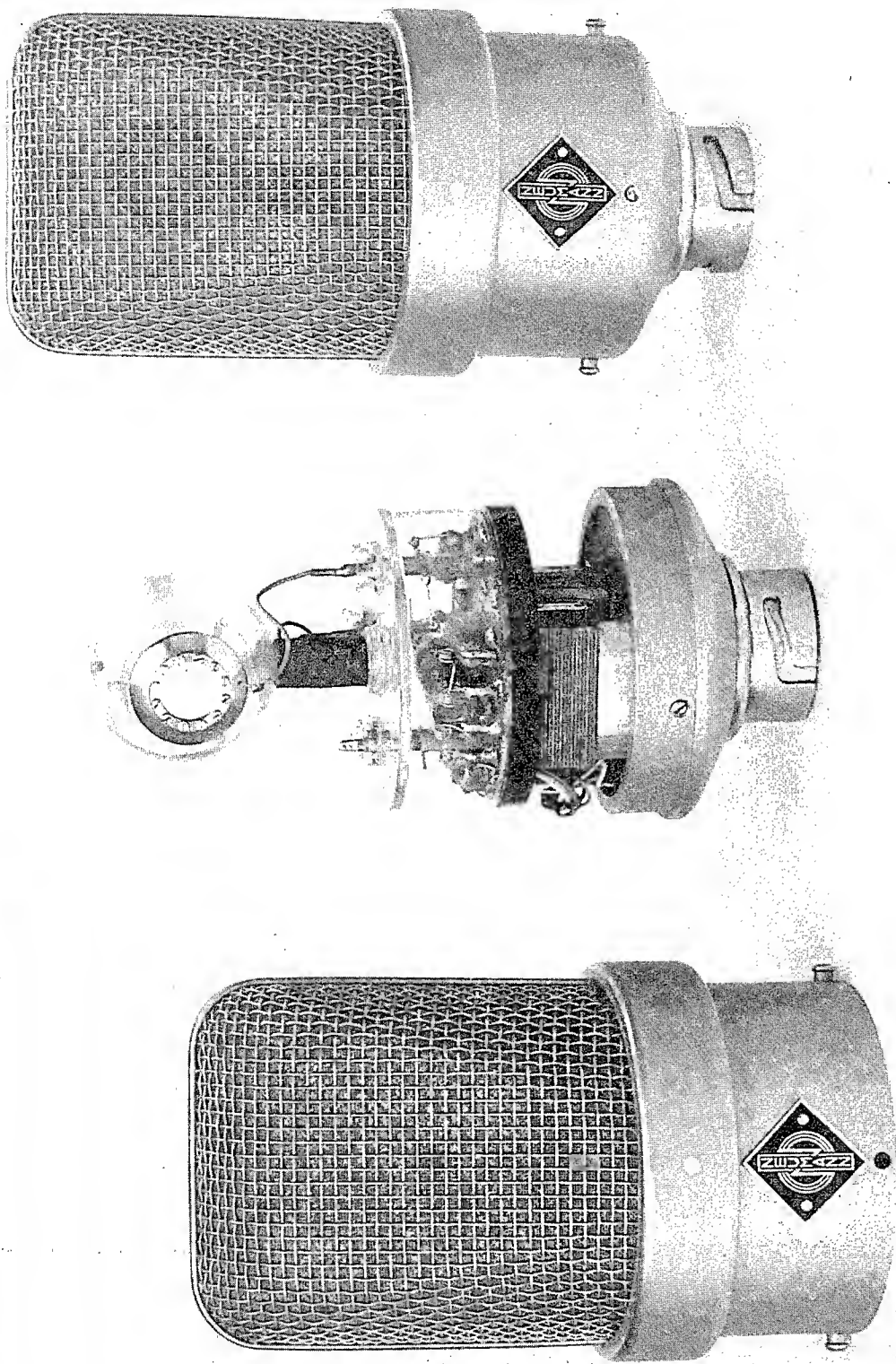
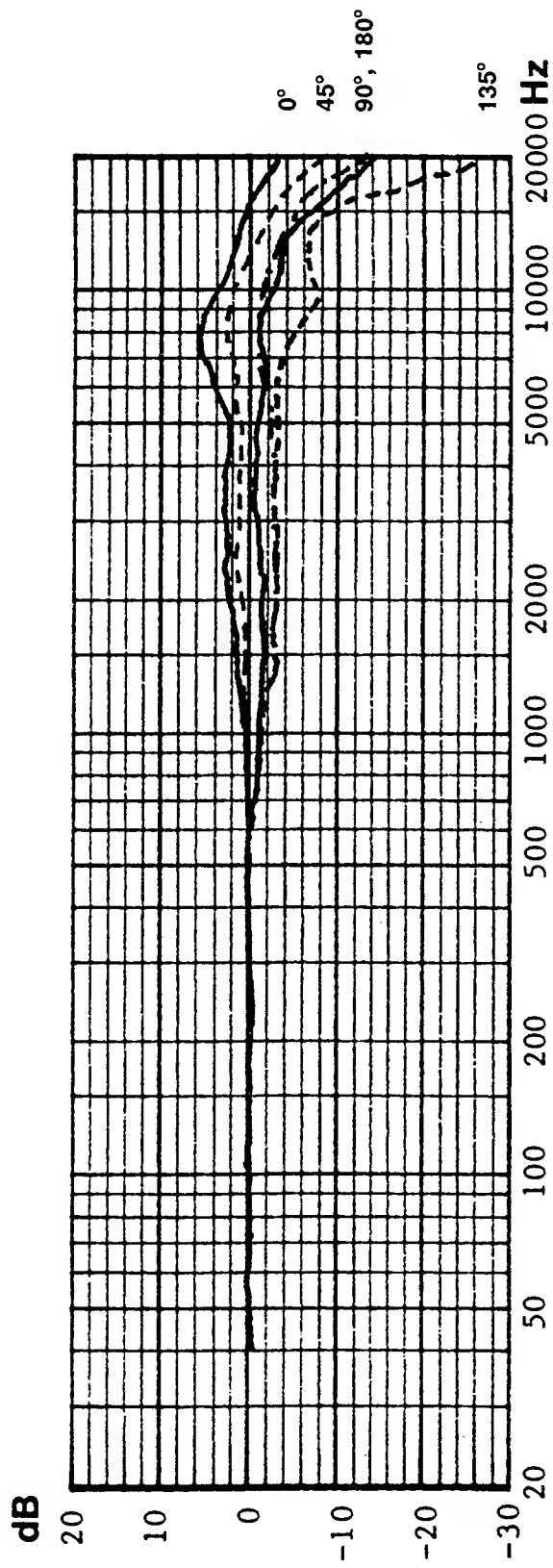


Abb. 6

Fig. 6

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— 0°, 90°  
 - - - 45°, 135°  
 - · - · 180°

Abb. 7  
Fig. 7

Frequenzgänge des Druck-Kondensatormikrophons TLM 50  
Response frequency characteristics of the TLM 50 pressure condenser microphone

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